Scand J Rehab Med 5: 156–159, 1973

MUSCLE SPINDLE RESPONSES TO STRETCH IN NORMAL AND SPASTIC SUBJECTS[1]

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As shown by Hagbarth & Vallbo (2, 3) impulses from intramuscular stretch receptors can be recorded with tungsten microelectrodes inserted into human muscle nerves in situ. Various types of stretch receptor units, including muscle spindle afferents, can be indentified and the recordings can be made stable enough to permit a thorough analysis of the signals coming in from the muscles during both passive movements and voluntary motor acts (5, 6).

In a study in progress, stretch receptor units from the calf muscles are sampled with a microelectrode inserted in the nerve to the medial gastrocnemius muscle in the popliteal fossa. This is done in healthy subjects as well as on spastic patients with greatly exaggerated Achilles tendon reflexes, the aim being to compare muscle spindle sensitivity to standardized muscle stretch in the two groups of subjects. Calf muscle stretch is brought about by dorsiflecting the foot in the ankle joint with the aid of a machine producing well controlled angular movements, variable in speed and amplitude. The subjects, lying in a comfortable position, are instructed to remain as passive and relaxed as possible during the tests and EMG-recordings are made from the leg muscles to check that these instructions are fulfilled.

So far 8 healthy subjects and 2 patients with calf muscle spasticity have been examined. Both patients had greatly exaggerated dynamic stretch reflexes and tendon jerks with easily elicitable foot clonus, but none of them exhibited any involuntary sustained contraction in the leg muccles during the test. One of them, who served as experimental subject on three occasions, had a lesion in the upper cervical region, the other had been operated for a ruptured cerebral aneurysm.

Multi-unit Recordings

Besides the single unit samplings, many multiunit recordings were made from the medial gastrocnemius nerves of the healthy and the spastic subjects. By recording the showers and trains of afferent impulses arising in response to standardized passive movements and by using an impulse integrator (with adjustable time constant) it is possible to get an analogue semiquantitative measure of how the overall neural inflow varies with changes in muscle length. Since the signal-to-noise ratio in the recordings varies with the intrafascicular position of the electrode and the shape and size of the electrode tip, one cannot easily obtain an absolute measure of the strength of the afferent responses in different individuals. However, in an attempt to compare receptor sensitivity in different subjects, we tried for each nerve examined to evaluate the average amplitude of the integrated stretch responses as obtained with different electrodes from various intrafascicular recording sites. So far we have been seeking in vain for signs indicative of increased dynamic and/or static receptor sensitivity in the spastic subjects. On the average, the bursts of afferent impulses appearing in response to Achilles tendon taps and joint movements stretching the calf muscles were of similar strength in all subjects examined. One could also in all subjects see how upon dorsiflection the static afferent inflow increased in an approximate linear fashion of the foot.

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[1] Paper read at the Symposium on Pathophysiology and Treatment of Spasticity, Swedish Society of Medical Science, Stockholm, November 1971.

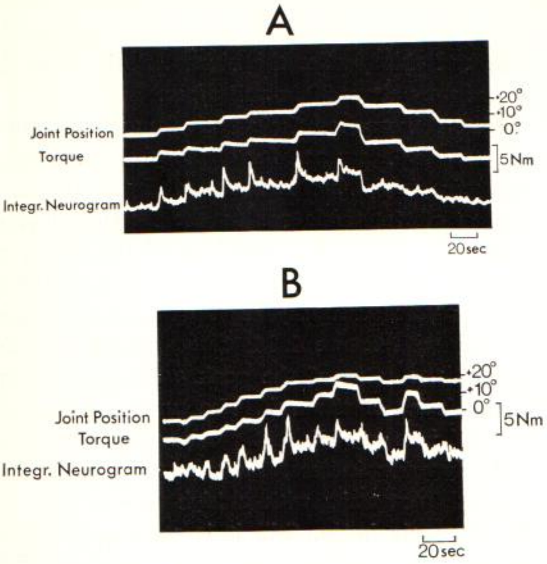

Fig. 1. Integrated multi-unit neurograms (time constant of RC-circuit 0.8 sec) showing how the afferent neural activity in the medial gastrocnemius nerve of relaxed subjects varies as the foot is moved up and down in a step-wise fashion with a speed of 1°/sec (not sufficient to induce any stretch reflexes). Torque signal obtained from a strain gauge attached to the foot plate. A, from a healthy subject; B, from a spastic patient with greatly exaggerated Achilles tendon reflexes. 0-position = foot at right angle.

The integrated neurograms in Fig. 1 (A from a normal and B from a spastic subject) show how the afferent multi-unit activity in the gastrocnemius nerve varies in strength as the foot is passively moved in a step-wise fashion up and down through the angular range, each movement proceeding with a speed of 1°/sec. Besides the increase in static activity with increasing dorsiflexion of the foot (upward goniometer deflections) the figure shows the dynamic responses during each stretch phase and also the temporary falls in neural activity upon each release of stretch. Note also how the »mechanical time constant" of the tissues is reflected in the torque trace (obtained from a strain gauge attached to the foot plate).

Unit Samplings

Figures 2 and 3 summarize our findings as regards the receptive properties of the stretch units sampled in the patients and in the healthy control subjects. Altogether 21 stretch receptor units have been sampled, 12 in the control subjects (Fig. 2 A) and 9 in the spastics (Fig. 2 B). The majority of these units were probably muscle spindle afferents; they all responded to local weak taps or sustained pressure on the gastrocnemius muscle belly and to passive dorsiflexion of the foot. The vertical thick bars in Fig. 2 illustrate how for each individual unit the *static firing rate* (measured 2 sec after the stretch movement had stopped) increased as the foot was dorsiflexed in a step wise fashion within an angular range of 36°, each step of 1.8° proceeding with a speed of 1°/sec. For each unit the base of the vertical bar in the *lower* diagram shows the foot angle at which the unit started to fire in a static fashion whereas the base of the corresponding bar in the *upper* diagram shows its static firing rate at that stage. The upward extension of the lower and upper bars indicate respectively how far up in dorsiflexion the unit could be followed (some of them were lost before the full stretch

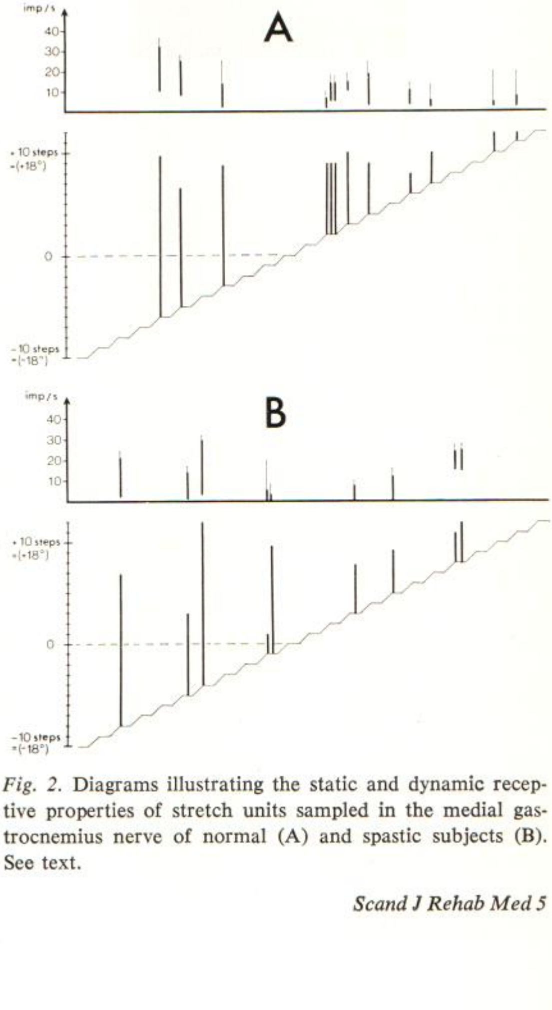

Fig. 2. Diagrams illustrating the static and dynamic receptive properties of stretch units sampled in the medial gastrocnemius nerve of normal (A) and spastic subjects (B). See text.

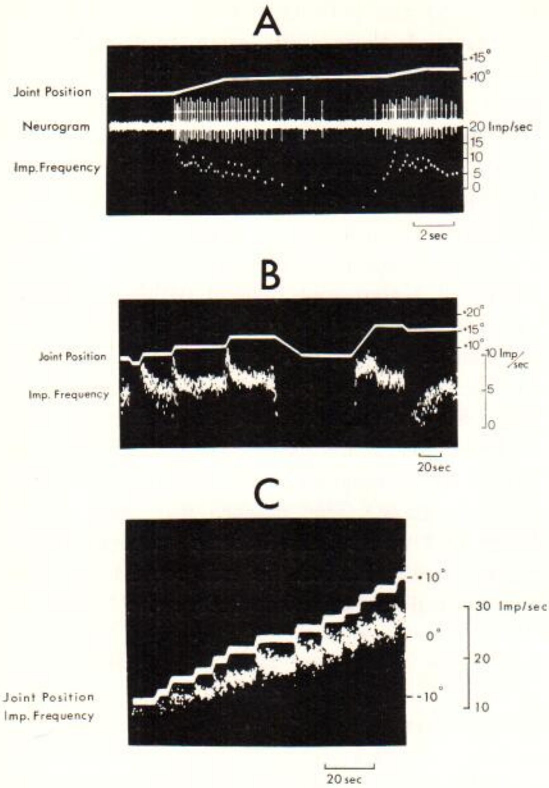

Fig. 3. Typical response patterns of calf muscle stretch receptor units to passive ankle joint movements with a constant speeds within the range of 0.25–1°/sec. The units were sampled in healthy subjects. Units with a high dynamic index, probably spindle primaries are illustrated in A and B. The dots on the spikes in the A neurogram illustrate the voltage level that the impulses have to surpass in order to be counted by the instantaneous rate meter. A stretch unit with a low dynamic index, probably a secondary spindle ending is illustrated in C.

program was completed) and how high its static firing rate then was. In the healthy subjects the majority of the units (9 of 12) did not show any static firing until the foot had passed the 0-position (90° between anterior profile of lower leg and foot plate) whereas in the spastics a larger proportion of units (5 of 9) were active already before the 0-position was reached. For all units the static firing rate increased in an approximately linear fashion with increasing muscle length and the average slope of the length-frequency curves was for the control subjects 1.9 impulses/step (range 0.7–5 imp/step) and for the spastics 2.5 impulses/step (range 1.2–5 imp/step). With the present small unit samples the differences observed are insignificant. For both the control subjects and the spastics the highest static rates observed were about 30 impulses/sec.

All units reached their peak frequency during the stretch phases and for each unit the maximal *dynamic firing rate* is indicated by a thin bar on top of the thick one in the frequency plots of Fig. 2. Thus, a comparison of the peaks of the thin and thick bars will give an estimate of the dynamic sensitivity of the receptors and in analogy with Crowe & Matthews (1) we have expressed the ratio of the peak values as the *dynamic index* of the unit. The units sampled did not fall into two distinct groups with respect to their dynamic indices; there was rather a continuum from units with a high to units with a low dynamic index. Still it is reasonable to believe that those with the highest index were primary spindle endings, whereas many of the others were secondaries. The average dynamic index for the 12 control units was 2.1 and the corresponding figure for the 9 units in the spastics was 1.6, again a difference too small to be statistically significant.

Figure 3 shows the typical response patterns of units with a high (A and B) and a unit with a low dynamic index (C). Note the typical, often prolonged pauses in the firing of the dynamic unit in **B** upon each release of stretch.

COMMENTS

In the 2 patients examined our multi- and single unit recordings have revealed no signs of increased *dynamic* spindle sensitivity in the spastic muscles; thus we conclude that the exaggerated dynamic stretch reflexes in these muscles were due to some sort of central hypersensitivity to the spindle inflow. As regards the *static* spindle sensitivity in the spastic muscles the multi-unit recordings revealed no abnormality and the single unit samples showed only some small, insignificant differences as compared with the controls. We now plan to extend our study to other spastic patients to see if we can possibly find two main groups of spastic syndromes, one *without* and another *with* signs of increased dynamic spindle sensitivity. In a recent study, Jacobi et al. (4) recorded muscle afferent nerve volleys induced by tendon taps in 12 healthy subjects and 8 patients with spastic paraplegia. They claim to have found what we have so far not seen in our study, namely that »the mechanical excitability of the muscle receptors was higher in the spastic patients".

We also plan to include rigid patients in our study. Preliminary multi-unit recordings from muscle nerves in Parkinsonian patients (8) indicate that in rigidity there is an increased outflow not only in the skeletomotor but also in the static fusimotor fibres, causing a sustained inflow from the spindles similar to that normally occurring during maintained voluntary contractions (2, 3, 5, 6, 7).

REFERENCES

1. Crowe, A. & Matthews, P. B. C.: The effects of stimulation of static and dynamic fusimotor fibres on the response to stretching of the primary endings of muscle spindles. J Physiol *174:* 109, 1964.
2. Hagbarth, K.-E. & Vallbo, Å. B.: Discharge characteristics of human muscle afferents during muscle stretch and contraction. Exptl Neurol *22:* 674, 1968.
3. — Single unit recordings from muscle nerves in human subjects. Acta Physiol Scand *76:* 321, 1969.
4. Jacobi, H. M., Krott, H. M. & Poremba, M. B.: Recordings of proprioceptive muscle afferents in man by various disorders of tendon reflex. Electromyography *10:* 307, 1970.
5. Vallbo, Å. B.: Slowly adapting muscle receptors in man. Acta Physiol Scand *78:* 315, 1970.
6. — Discharge patterns in human muscle spindle afferents during isometric voluntary contractions. Acta Physiol Scand *80:* 552, 1970.
7. — Muscle spindle response at the onset of isometric voluntary contractions in man. Time difference between fusimotor and skeletomotor effects. J Physiol *218:* 405, 1971.
8. Wallin, B. G., Hongell, A. & Hagbarth, K.-E.: Recordings from muscle afferents in Parkinsonian rigidity. *In* New Developments in Electromyography and Clinical Neurophysiology (ed. J. E. Desmedt), vol. 3. 263, Karger, Basel, 1973.

Key words: Neuromuscular spindles, paralysis, spastic, reflex, tendon.

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